Phys 230
Fall 2012

Intermediate Dynamics: Class Exam I

17 September 2012

Name: Solution **Total:** /50

Instructions

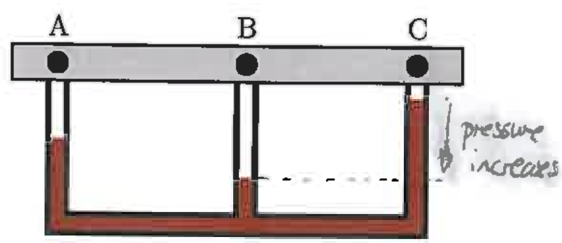
- There are 6 questions on 5 pages.
- Show your reasoning and calculations and always justify your answers.

Physical constants and useful formulae

$\rho_{\text{water}} = 1.00 \times 10^3\,\text{kg/m}^3$	$1\,\text{atm} = 1.01 \times 10^5\,\text{Pa}$	$T_K = T_C + 273$
$N_A = 6.02 \times 10^{23}\,\text{mol}^{-1}$	$k_B = 1.38 \times 10^{-23}\,\text{J/K}$	$R = 8.31\,\text{J/mol K}$

Question 1

Air flows from left to right through a pipe of possibly variable diameter, which is enclosed in a gray tube as illustrated. The axis of the pipe is horizontal. Another set of pipes containing a liquid is connected to the pipe transporting air at three locations labeled A, B and C. Rank the fluid pressures, air speeds and diameters of the pipe at locations A, B and C. Explain your choice.



In order of increasing pressure $\quad P = P_0 + \rho g h.$

$P_C < P_A < P_B$ 2

Use Bernoulli for flow through pipe $\quad \frac{1}{2}\rho v^2 + \rho g y + P = \text{const}$

$\Rightarrow \frac{1}{2}\rho v^2 + P = \text{const}$ since $y = \text{const}$ 3

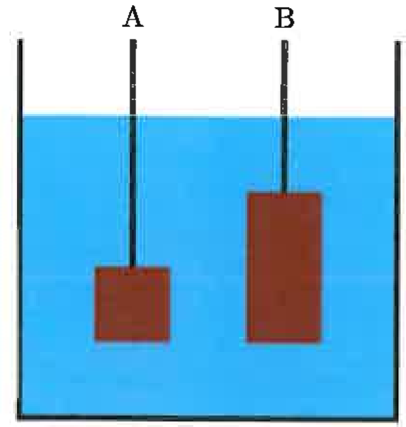
$\Rightarrow V_B < V_A < V_C$ /8

Continuity equation $\Rightarrow AV = \text{const}$ 2

$\Rightarrow A_C < A_A < A_B \Rightarrow d_C < d_A < d_B$

Question 2

Two blocks are suspended at rest in the same fluid and both are completely immersed. The blocks have the same mass but the volume of block B is double the volume of block A. Which of the following (choose one) is true of the tensions in the strings?



a) $T_A = T_B$

b) $T_A > T_B$

c) $T_A < T_B$

d) Depends on the depth at which A and B are suspended.

rest $T = mg - F_B$ $F_B = \rho V_{displaced}\, g$

↳ larger for B ⇒ T smaller for B.

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Question 3

A small cubic container has sides of length 0.020 m and contains air. The pressure within the container is 4.0×10^{-2} Pa. Assume that the air is a diatomic ideal gas. Determine the total internal/thermal energy of the air within the container.

$E_{th} = \frac{5}{2} nRT$ diatomic. $nRT = PV$

$= \frac{5}{2} PV$ +3 $V = (0.020\text{m})^3$ +1

$P = 4.0\times10^{-2}\text{Pa}$

$\Rightarrow E_{th} = \frac{5}{2}(4.0\times10^{-2}\text{Pa}) \times (2.0\text{m}\times10^{-2})^3 = 80\times10^{-8}\text{J}$

+2 $= 8.0\times10^{-7}\text{J}.$

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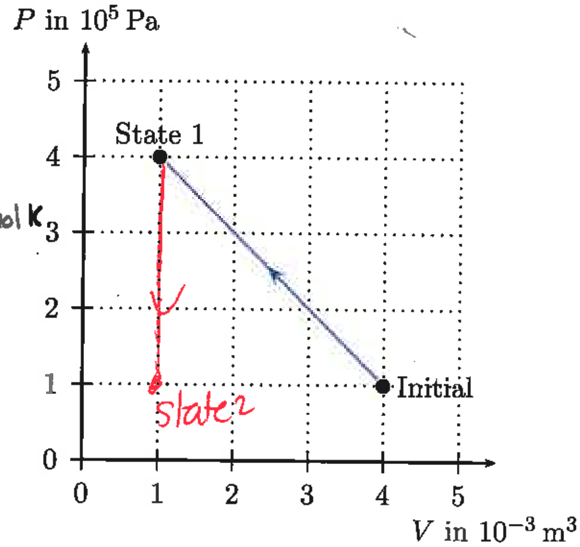
Question 4

A container holds 0.10 mol of a monoatomic ideal gas. The gas is in the illustrated initial state and first undergoes the compression to state 1 indicated by the line on the PV diagram. This is followed by a reduction in pressure at a constant volume to state 2, which has the same pressure as the initial state.

a) Determine the temperatures of the gas in states 1 and 2.



$PV = nRT$ +2

$\Rightarrow T = \frac{PV}{nR} = \frac{PV}{0.10\text{mol} \times 8.315\text{J/mol K}}$

$T_1 = \frac{P_1 V_1}{0.831\ \text{J/K}}$

+2

$= \frac{4.0\times10^5\text{Pa} \times 1.0\times10^{-3}\text{m}^3}{0.831\ \text{J/K}}$

$= 481\ \text{K}$

$T_2 = \frac{P_2 V_2}{0.831\text{J/K}} = \frac{1.0\times10^5\text{Pa}\times 1.0\times10^{-3}\text{m}^3}{0.831\ \text{J/K}} = 120\ \text{K}$

+2

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b) Determine the work done on the gas, the change in thermal energy and the heat supplied for *each of the two parts* of the process. Enter your results in the table on the next page.

$\Delta E_{th} = W + Q$

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$\Delta E_{th} = n C_v \Delta T$

$= \frac{3}{2} nR\Delta T$ monoatomic.

$= \frac{3}{2}\Delta(PV)$ +3

Question 4 continued ...

For $i \to 1$ $\quad \Delta T = 0 \Rightarrow \Delta E_{th} = 0$ +1

$1 \to 2$ $\quad \Delta T = -361\,K \Rightarrow \Delta E_{th} = -\frac{3}{2}$ +1 $0.10\,mol \times 8.31\,J/mol\cdot K \times 361\,K$

$= -450\,J$

$W = -\int P\,dV$ +3

For $1 \to 2$ $\quad dV = 0 \Rightarrow W = 0$ +1

$i \to 1$ $\quad |W| =$ area under PV = +1 7.5 blocks × area 1 block

$= 7.5 \times 100\,J = 750\,J$

$W > 0$ since compression

Finally $Q = \Delta E_{th} - W$ completes the table. +2

Stage	$\Delta E_{\rm th}$	Q	W
Initial → 1	0 J	−750 J	750 J
1 → 2	−450 J	−450 J	0

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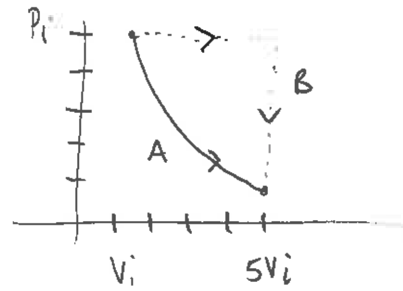

Question 5

Two identical samples of an ideal gas each initially have the same pressure, P_i, volume, V_i and temperature T_i. Sample A undergoes an isothermal expansion to volume $5V_i$. Sample B undergoes an expansion at constant pressure to volume $5V_i$ and after this a constant volume process which takes it back to its original temp T_i. Which of the following (choose one) is true regard the heat that enters or leaves each gas sample?

$\Delta E_{th} = 0$ since $\Delta T = 0$ for both.

a) $Q_A = Q_B$
b) $Q_A < Q_B$
c) $Q_A > Q_B$

$\Rightarrow W + Q = 0$

$\Rightarrow Q = -W$.

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$W < 0$ for both so

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$-W_B > -W_A$ since area is larger for B

$\Rightarrow Q_B > Q_A$

Question 6

Two moles of neon, a monoatomic gas, initially at pressure P_i are compressed isothermally, reaching a final state with pressure $P_f = 2P_i$. The initial rms average speed of the gas molecules was 500 m/s. Assume that the gas is an ideal gas. Which of the following (choose one) is the final rms speed?

a) 1000 m/s
b) $500\sqrt{2}$ m/s
c) 500 m/s
d) 250 m/s
e) $\frac{500}{\sqrt{2}}$ m/s

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T is constant

$$V_{rms} = \sqrt{\frac{3 k_B T}{m}}$$

$\Rightarrow V_{rms}$ same

Explain your answer.

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